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THE TWO SCHOOLS OF PLANT PHYSIOLOGY AS AT PRESENT EXISTING IN GERMANY AND ENGLAND.[1]

By E. L. Gregory.

It is an admitted fact that the science of vegetable physiology has reached a stage of development in the different scientific schools of Europe in advance even of the same department of animal life. It is also well-known that in Germany the three most prominent men who have contributed to this result are Naegeli, Sachs and Schwendener.

The expression "Two Schools of Plant Physiology" is one, however, which requires some explanation, and possibly, defense. It implies that the various conflicting theories which are at present occupying the botanical world may be traced back to two distinct sources, which, if true, is a fact not so universally known or admitted.

All scientific students whose knowledge of botany extends as far as a mere superficial acquaintance with the ordinary text books, are more or less familiar with the position occupied by Sachs. His text book may be said to be the first general text book on the science of the plant kingdom; that is, the first reckoning from that time when our knowledge of the phenomena occurring in this kingdom and of the laws governing them was considered sufficient to warrant the expression "Science of the vegetable kingdom." The various text books of general botany written before this time are now considered of little worth except as historical records. It is partly owing to this fact of priority that all our later text books bear so strongly the impress of Sachs' personal teaching. His name is constantly repeated in connection with the principles which he advocates, whether these principles owe their discovery to him or his predecessors. It is, therefore, impossible to read any of the ordinary text books without becoming somewhat familiar with the ideas and theories advocated by Sachs.

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[1] Read before the meeting of the American Society of Naturalists, Phila., Dec. 29, 1891.

It is, however, quite different in the case of the works of the two others, Naegeli and Schwendener; especially is this true of the first named, whose long and busy life presents a record of intellectual labor and achievement possibly unequaled and probably unsurpassed by any other scientist of the present generation. He was a teacher, like the other two, and not only retained his position as professor of botany in the University of Munich, but fulfilled all its duties up to the day preceding his death. Unlike the other two, he seemed to lack in some degree that quality of mind usually so predominant in teachers, namely, the necessity of impressing its mode of thought on other minds. He was a sharp, keen, and logical thinker, and directed his strongest efforts in search of unknown truths. Although he may not in any sense be considered the founder of a school, it would be impossible to discuss fairly the present condition of this science without referring to the influence of his thought and labor.

The object, therefore, of the following paper is to consider briefly the present condition of plant physiology as it now stands in Germany and England, represented as under the controlling influence of two men, Sachs and Schwendener. A paper claiming such an object must necessarily contain much that is personal in character; it may, therefore, be allowed the writer to disclaim, at the outset, all design of personal defense or attack, whatever the appearance may be, the purpose being to show, as clearly as possible in such brief limits, the principal features presented by the teachings of two men whose methods and theories are in some respects antagonistic.

Again, in farther explanation of this purpose, as before intimated, the teachings of Sachs have become familiar through the works and text books of his numerous students and disciples. It is, perhaps, quite safe to say there is not a single text book on plant physiology which in all its important features is not based on the principles expressed and advocated by Sachs.

On the other hand, it is equally true that if there is a school of scientists opposed to many of these theories it has not yet reached the position to lay claim to this title by the publication of text books. In short, this school is of a date so recent that comparatively few of its theories are accessible to the English-speaking world. As an illustration of this fact, one of the most strongly contested points of disagreement between Sachs and Schwendener is in reference to the cause of twining stems. Vines in his text book of physiology gives the theory of Sachs and also those of various later writers, and among others refers briefly to that of Schwendener in these words: "Schwendener attributes the twining to circumnutation and to an antidromous torsion." Professor Schwendener said of this after reading it carefully, "This is quite erroneous; he has entirely misunderstood my theory. According to my explanation of this fact, torsion is only an effect of twining and not a cause."

In that department of plant physiology which deals with nutrition there are fewer differences of opinion than in that of the physiology of movement. It is in the latter field especially that Professor Schwendener has worked out solutions of various problems differing vitally from those of any other physiologists. In fact, his fondness for mechanical questions has given him the reputation of a specialist in the narrow sense of the term. Added to this is the fact that his discussions of several theories are so abstruse as to render them difficult even for the mature students who are likely to choose such studies in the German Universities. Thus, in speaking of his work on the position of leaves, he said it was extremely difficult for his advanced students who had been under his own training to follow his lectures on this subject; that with all his illustrations and models which he had constructed for these lectures it was often necessary for him to go twice through the same lecture, and that he never felt certain of the number who had conquered the subject until he had tested them in the laboratory.

Again referring to Vines, who may be considered at once the best exponent of the views of the English botanists and a fair disciple of Sachs, he says of this: "Schwendener has constructed an extremely simple theory regarding the position of leaves."

This implication of narrowness and specialization is, in the writer's opinion, extremely unjust and lacking foundation in truth. The fact that he chooses to devote special attention to the mechanical problems connected with the subject of growth by no means proves his unwillingness or inability to cope with all the questions connected with the subject, those referring to plant nutrition as well as those of growth. It is, however, unquestionably true that the habit of reasoning induced by studies of this nature is such as to lead to a different treatment of the questions of plant nutrition from that adopted by most of his cotemporaries.

For example, in all those questions included in the general term, "plant-metabolism," his views may be said to be strongly conservative when contrasted with those of the school of Sachs. Among the latter are many who express the hope of being able to trace the course of the changes connected with these processes in such a manner as to prove by actual weight and measurement the principle of conservation of energy. There are no text-books on plant physiology except, perhaps, a few elementary ones, in which the author does not run through some mode of reasoning either attempting to prove it, or show how it may possibly be proven. Starting with the process of CO_2 assimilation as it is called, an arbitrary equation is formed which may, or may not, show the changes undergone in this single process. The equation is purely arbitrary, no proof whatever can be given of its truth, except that it expresses how the relations might be adjusted. A much more difficult matter is undertaken by those who try to explain the process occurring in the changes caused by respiration. All the German text books, Sachs, Pfeffer, Weisner, Reinke, Detmer and others, all have tried to give some hypothesis which may explain the exact nature of the changes by which the rhythm of destructive and constructive metabolism is kept up in the living processes of the plant. The physicist and the chemist both are able to carry on their computations, weigh and measure to the smallest fraction and verify their theories by actual demonstration. So far the botanist has tried in vain to apply the weights and measures of Physics and Chemistry to the results of action connected with the living portions of the plant. The difficulty lies not only in the extreme delicacy of the material in question but in the danger of interference with the processes as they go on.

Schwendener and his followers claim that we have not yet reached that point in the development of the science where such questions may be asked with a reasonable hope of a satisfactory reply. Our knowledge is too meagre and our means of acquiring more are as yet inadequate. In other words, they claim that the methods now used are incorrect, inasmuch as they do not aim at constructing a theory which shall satisfactorily account for certain facts, but they presuppose the existence of the facts, and the methods result, for the most part, in mere conjectures and speculations which count for nothing.

Whether this view be true or false it is unquestionably the source of the implication of narrowness and onesidedness before referred to, as obtaining against Schwendener among his own cotemporaries and his own country. Even here, however, it cannot be said that there is any actual difference in opinion between the two schools, only that the methods and results so far obtained by the one, are held in very light esteem by the other. It is very different when we come to the various problems connected with the growth and motion of plants. It is in this field particularly that the difference of opinion between the two men leads to positive difference in the teaching and modes of treatment of several important questions.

Schwendener gives, each year, a course of advanced lectures covering the following ten subjects.

1st. The mechanical principle in the development structure.
2nd. Theory of leaf position.
3rd. Mechanics of stomata.
4th. Bending of the medullary rays in eccentric secondary growth in thickness.
5th. Torsion, as caused by hygroscopical changes.
6th. Ascent of sap; hydro-mechanics of.
7th. Mechanics of twining.

8th. Nyctitropic movement of leaves.

9th. Mechanics of irritation movements.

10th. Flying apparatus of fruits and seeds.

All of these ten subjects he treats from his own standpoint, giving the results of his own experiments and study, except, perhaps, the last one, which is sometimes omitted for lack of time, and it is one to which he has given less attention than to the remaining nine.

From these ten subjects there may be selected three in which his opinions are diametrically opposed to those of Sachs and his followers; several of the rest are not treated at all in the latter school; and to the three here mentioned may be added two more important questions in which Schwendener differs radically from other physiologists. He gives the following list as including the most important questions of difference between his opinions and those of Sachs.

1. The problem of the ascent of water.
2. Cause of the year's ring.
3. Bending aside of the medullary rays by the rind pressure.
4. Mechanism of twining stems.
5. Turgor, its influence on growth of cell wall.

These may be said to represent fairly the important points which serve to separate the new school from the old. It is hoped a brief consideration of some portions will be sufficient to vindicate the right of the new school to this title, claimed for it here for the first time.

The problem of the water ascent is one in which Schwendener not only differs from Sachs but also from a large number of other botanists, who cannot be considered the followers of Sachs. The theory held by the latter and his school is, that the water rising in stems more than 30 feet high is for the most part carried through the lignified cell-walls. Schwendener and a large number of other botanists believe it is carried through the lumina of the cells. The difference, however, in the theory as taught by Schwendener and these other botanists, some of whom are, in other respects, his followers and adherents, is that they claim to give an exact explanation of the manner in which this is done. On the other hand, Schwendener, who treats this question at length, denies our ability at the present condition of botanical knowledge to explain how the water is driven up. The agent he gives, but of the manner in which this agent works, he says we know nothing.

His treatment rests on a long series of experiments, the last of which were made several years ago and conducted as follows: A forester several miles out of Berlin was authorized by the government to allow the forest under his charge to be invaded for scientific purposes, and a small lodge was built where one of Schwendener's assistants remained for several weeks, in fact about eight weeks, so that the experiments might have an uninterrupted course, the professor going over every few days to perform the manipulations himself, while the assistant remained to watch and report the results.

(*To be continued*)